DOES EARLY MICROMOTION OF FEMORAL STEM PROSTHESSES MATTER?

4-7-YEAR STEREORADIOGRAPHIC FOLLOW-UP OF 84 CEMENTED PROSTHESSES

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Roentgen stereophotogrammetry was used to measure the migration of the centre of the femoral head in 84 cemented Lubinus SP I hip arthroplasties (58 primary operations, 26 revisions). Four to seven years later, seven femoral components had been revised because of painful loosening. These implants showed greater subsidence, medial migration and posterior migration during the first two postoperative years than did the hips which had not been revised. Six months after operation, subsidence of more than 0.33 mm combined with a total migration of more than 0.85 mm predicted an increased risk of subsequent revision; the amount of subsidence at two years was an even better predictor. The probability of revision was greater than 50% if the subsidence at two years was 1.2 mm or more.

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Analysis of conventional radiographs has been the standard method for predicting later clinical failure of hip prostheses. One problem is to define criteria for radiographic loosening. Brand, Pedersen and Yoder (1986) found that radiographic loosening rates may vary by a factor of at least two depending on the criteria used. The importance of a given risk factor as a predictor of late loosening will change by at least the same amount. The introduction of more accurate techniques to measure prosthetic migration could therefore prove useful in the evaluation of rival methods of fixation.

To improve the sensitivity of radiographic measurements several stereoradiographic methods have been used (Probst, Herp and Leidel 1978; Lippert et al 1982; Green et al 1983; Djerf, Edholm and Hedbrant 1987). Mjöberg et al (1985) compared scintigraphy, arthrography and roentgen stereophotogrammetric analysis (RSA) (Selvik 1974, 1989) to detect mechanical loosening of cemented hip prostheses and concluded that measurement of migration by RSA was the most sensitive method. Later studies have used RSA to measure the early migration of many designs of cemented and uncemented femoral prostheses (Mjöberg et al 1986; Wykman, Selvik and Goldie 1988; Nistor et al 1991; Franzén, Mjöberg and Önnerfält 1992; Wykman and Lundberg 1992; Kärrholm and Snorrason 1993; Søballe et al 1993), but the clinical implications of the recorded migration have not been established.

Increased pain has been associated with uncemented femoral stems which showed early subsidence of 1 mm or more (Kärrholm and Snorrason 1993), but this observation has not been confirmed by others (Nistor et al 1991). Ryd et al (1993) found that early and continued migration of the tibial component in knee arthroplasty was associated with later revision whereas implants which became stable within the first one to two years did not proceed to clinical loosening. To clarify the clinical significance of early migration of cemented femoral stems, we studied all the patients who had had RSA studies at the Northern University Hospital and who had been followed up for about five years.

PATIENTS AND METHODS

Between 1984 and 1987, we performed prospective studies to measure the micromotion of the femoral component by RSA on 84 cemented hip arthroplasties in 81 patients. There were 33 men and 48 women with a median age of 68 years (41 to 83). The diagnoses were primary osteoarthritis (52 hips), rheumatoid arthritis (16), sequelae of femoral neck fracture (15) and dysplasia (1). Fifty-eight hips had primary arthroplasties, eight had revisions of surface replacements, and there were 18 revisions of cemented or uncemented stem prostheses. The early migrations of some of these implants, up to two
years after operation, have been previously reported (Snorrason and Kärholm 1990).

**Operative technique.** The hip was approached through a posterior (83 hips) or a lateral approach (one hip) without trochanteric osteotomy. The medullary canal was plugged before retrograde filling with cement. High-pressure lavage, tamponade of the femoral canal and vacuum mixing of cement were not used. During the operation, three to seven spherical tantalum markers 0.8 mm in diameter were inserted into the proximal femur. The prosthesis used was a cobalt-chrome Lubinus SP I prosthesis (W. Link, Germany) with a 32 mm head and a stem length of 15 cm (77 hips) or 17 cm (7 hips). Cemented all-polyethylene cups were used in all cases.

**Analysis.** RSA was used to measure prosthetic migration (Selvik 1974, 1989; Nyström 1990; Söderqvist 1993). The first examination was done 1 day to 2 months after surgery and thereafter at 6 months and 1, 2 and 5 to 8 years. Migration of the centre of the femoral head was taken to represent the movements of the implant (Baldursson et al 1979). At the start of this study we used a separate calibration examination and reference plates (Kärholm 1989); the method was later changed to the use of a cage placed beneath the patient for greater accuracy. The precision of the measurements was calculated as the absolute mean value ± 2.7 SD (99% confidence limit) of the recorded translations between two examinations done at an interval of about 15 minutes. These so-called double examinations were done using the older technique to avoid underestimation of the error. The values obtained corresponded to femoral head translations of 0.36 mm in the medial/lateral direction, 0.21 mm in the proximal/distal direction, and 0.94 mm in the anterior/posterior direction. The corresponding value for the vectorial sum of these translations was 0.95 mm.

At the last follow-up 13 patients (13 hips) had died and 62 still had the prosthesis in place; three of these could not be examined because of serious disability not related to the hip implant. In a further four hips the stereoradiographs could not be accurately measured because of inadequate visualisation of the tantalum markers or marker instability. The 55 hips that remained had a median follow-up of 5 years 10 months (4 years 9 months to 7 years 10 months).

Nine femoral components had been revised. In seven this was because of thigh pain and radiographic loosening. The revisions had been done at a median 5 years and 1 month after operation (4 years to 7 years 10 months). RSA examinations had been done less than two months before revision surgery in six of these cases. The hip that was revised at four years had not been stereoradiographically examined after two years. Six of these seven hips had been revised earlier.

One patient had revision because of groin pain and radiographic loosening of the acetabular component. The surgeon also exchanged the femoral component, although it appeared to be securely fixed. This hip was excluded because we were unsure whether any of the symptoms was caused by femoral component instability. The last patient was revised eight years after the insertion of a primary arthroplasty because of osteolysis.

**RESULTS**

**Hips not revised.** There was a tendency to medial, distal and posterior migration of the centre of the femoral head (Figs 1 to 3). After five to six years medial migration of more than 0.36 mm was recorded in 26 hips, and lateral
migration of more than 0.36 mm in four hips. Two hips migrated more than 1 mm in these directions (2.2 mm medially; 1.1 mm laterally). Twenty-five hips had subsided 0.22 mm to 4.2 mm and seven had migrated proximally 0.28 mm to 1.2 mm. Posterior migration of 0.97 mm to 4.8 mm was found in 33 hips and anterior migration in five (1 to 3.6 mm). Four to seven years after operation 49 of the 55 prostheses had shown significant migration (p < 0.01) along at least one of the three coordinate axes.

Linear regression analysis using the six-month, one-year and two-year values revealed that the best prediction of the five- to eight-year status was obtained from the amount of migration at two years (adjusted r^2 for the four types of migration = 0.69 to 0.80).

**Revised hips.** In the group revised because of pain there was more migration up to 24 months than in the hips not revised regardless of the type of motion analysed (p < 0.001, repeated measurements ANOVA, Figs 1 to 4). At the two-year examination a combination of medial, distal and posterior migration above the 99% confidence limit was found in six of the seven cases revised and in only one of the cases not revised (p < 0.000005, Fisher’s exact test). At the last follow-up before revision the centre of the femoral head had displaced medially, distally and posteriorly in all seven hips. The total translation at two years ranged between 1.3 mm and 15.9 mm and at the last examination before revision was 4.6 mm to 24.4 mm.

**Prediction of revision.** Logistic regression analysis based on patient factors (gender, age, diagnosis), type of operation (primary surgery, revised surface or revised stem prosthesis), time to first postoperative examination and stereoradiographic data from the 6-, 12- and 24-month examinations revealed that the amount of subsidence after two years was the best predictor of revision (60 of 62 cases correctly classified, chi-squared test = 28.5, p < 0.00005). Inclusion of the type of operation improved the model (chi-squared value increased to 35.7, p value for improvement to 0.03), but did not result in any more correctly classified cases. Thus in the group that was revised, subsidence of more than 1 mm was noted in six of seven cases at the two-year examination. In the group not revised one of 55 cases had subsided more than 1 mm at this time. The cut-off values for the probability of revision to exceed 50% and 95% (disregarding type of index operation) were respectively 1.2 mm and 2.6 mm of subsidence at two years.

Excluding the one-year and two-year observations we evaluated the predictability of the six-month data. This showed that the subsidence (chi-squared test = 19.5, p < 0.00005) and the amount of total translation (chi-squared value increased to 31.6, p value for improvement = 0.0005) could be used to classify correctly all the cases not revised and five of the seven revised hips. The correctly classified cases subsequently revised had subsided more than 0.33 mm and showed a total migration of more than 0.85 mm. This amount of migration did not occur in any of the hips that were still in situ at the last follow-up.

**Revision because of osteolysis.** One 62-year-old man developed localised osteolysis at two years. He was followed continuously, but did not agree to revision until eight years after the operation, by which time the osteolysis had become multifocal (Fig. 5a). He had little or no pain. Subsidence between 0.09 mm and 0.38 mm was recorded at seven successful RSA examinations, six months to eight years after the operation (Fig. 5b) and the migrations in the other directions were insignificant. At revision the prosthesis could be easily extracted from the cement and was found to be surrounded by small amounts of

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**Fig. 3**
Anterior/posterior migration (mm) of the centre of the femoral head (mean and standard error).

**Fig. 4**
The vectorial sum of the medial/lateral, proximal/distal and anterior/posterior translations of the centre of the femoral head (total translation, mean and standard error).
granulated debris. The cement mantle was well fixed to the bone except in Gruen zones 5 and 6 (mediodistally) where it was thin and fractured.

DISCUSSION

This study was begun when RSA measurements of cemented femoral hip prostheses were restricted to recording the movement of the femoral head. In later studies (Nistor et al 1991; Kårrholm et al 1992; Kårrholm and Snorrasen 1993) the use of tantalum markers inserted into different parts of the prosthesis allowed the measurement of rotation and migration of the proximal and distal parts of the stem, revealing that rotation of the femoral component is common about an axis close to the long axis of the femur (Kårrholm and Snorrasen 1993). The anterior/posterior migration observed in this study could in most cases be interpreted as the result of such prosthetic rotations and medial migration could correspondingly be interpreted as the result of tilting into a varus position.

Gruen, McNeice and Amstutz (1979) described four types of failure of cemented hips, three of which included or could include varus tilting. Our stereoradiographic data revealed a consistent pattern of failure which included medial, distal and posterior migration, the last being very difficult to detect on conventional radiographs. Most of the hips which were not revised showed a similar pattern of migration, which can be explained by the direction of the forces acting at the joint (Davy et al 1988). The femoral implants in the present study were all of similar design, curved in the anteroposterior direction to fit the curved shape of the femoral canal. The pattern of failure may be different for a different design and may also depend on the type of fixation used. RSA of nailed femoral neck fractures which are subjected to similar forces, however, has shown similar distal and posterior displacement of the femoral head (Ragnarsson and Kårrholm 1991; Ragnarsson et al 1993).

The inclusion in our study of revision hip arthroplasties may mean that the pattern of failure which we observed is not that seen in primary hip replacement. RSA data on uncemented hips, however, have shown that subsidence of 1 mm or more during the first two postoperative years is associated with an increased risk of revision. Kårrholm and Snorrasen (1993) measured subsidence of more than 1 mm in seven of 18 smooth uncemented ribbed stems after two years. Two of these were revised because of pain less than five years after operation (unpublished observation). Wykman et al (1991) reported that 13 of 72 uncemented HP-Garche prostheses had to be reoperated on in less than four years and that a further five hips were candidates for reoperation. Earlier RSA studies of eight hips had shown a mean subsidence of about 2 mm two years after surgery (Wykman et al 1988). Nistor et al (1991) found subsidence of about the same amount in ten uncemented LMPCH hip prostheses one of which had been revised at three to four years. Continuing rotation into retroversion was recorded throughout the observation period and was thought to be predictive of later problems.

Previous clinical studies have shown that the need for revision for loosening of cemented femoral components increases linearly (Morscher and Schmassmann 1983) and may even decrease somewhat with time (Sutherland et al 1982), whereas revision for cup loosening has an exponential increase (Charnley 1979; Morscher and Schmassmann 1983). Cup revision is seldom required less than eight years after operation. The Lubinus SP I
prosthesis had a low revision rate in the Swedish multicentre investigation when used as a primary prosthesis (Malchau, Herberts and Ahnfelt 1993). In our series of total hip replacements, using a second-generation cementing technique, migration was demonstrated in all but six of the 55 hips which had not been revised. The significance of this movement is not known. Certainly, there will be more revisions in this series of cases during the coming five to 15 years implying that the limits of ‘acceptable’ early migration as derived from our experience so far will have to be narrowed if long-term clinical stability is the goal.

According to calculations performed by Huiskes (1993), debonding at the cement-implant interface increases the cement and cement-bone interface stresses. We do not know whether the small migrations which we observed in the cases not yet revised correspond to movement between the implant and the cement or between the cement and the bone. Probably both occur (Gie et al 1993) sometimes simultaneously at different sites on the interfaces, due to an incomplete or a fractured cement mantle. In our series the causes of revision were primarily mechanical. Cement-bone or cement-implant loosening slowly progressed or sometimes occurred in a stepwise fashion due to cement fracture. The biological response to this process has been described previously (Willert, Ludwig and Semlitsch 1974; Goldring et al 1983; Santavirta et al 1990; Horowitz et al 1993).

In the patient with granulomatous osteolysis a varying rate of subsidence was observed from six months to eight years suggesting that the stem migrated within the cement mantle. The finding of debris along the entire length of the stem within a well-fixed cement mantle supports the theory of early debonding. Thereafter, micromotion could be of importance in causing the transport of joint fluid and debris around the stem. Leakage of joint fluid through defects in the cement (Anthony et al 1990; Maloney et al 1990) may have induced the osteolysis by a pressure effect (Anthony et al 1990). The response of bone cells to cytokines transported to the defect by joint fluid or locally produced by macrophages may also be important (Vaes 1988; Ohlin, Johnell and Lerner 1990).

Micromovements of the stem within a strong intact cement mantle may be compatible with prolonged survival of the implant provided that the amount of wear is within a certain limit. Slight proximal migration of the femoral head, which we observed in a few implants, could be an effect of rotation of the prosthesis posteriorly. If the mantle is rigidly fixed, displacement and tilting of the comparatively wide collar of the Lubinus prosthesis could force the femoral head slightly proximally. Proximal migration seemed to be a good prognostic sign; it was not seen in any of the cases which failed.

Determination of early micromotion of femoral stems is of interest because important information can be obtained within six to 24 months after surgery and before migration is evident on conventional radiographs. Because of its great accuracy, RSA comparison of different prostheses or methods of fixation can be restricted to small numbers of patients. In our study, subsidence of the femoral head of 1 to 2 mm during the first two years after operation implied an increased risk of later revision. Probably the amount of acceptable early migration is smaller than this for optimum long-term results, especially in young active patients.

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REFERENCES


